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AN INVESTIGATION OF LOCALIZED CORROSION OF AL 2024 UNDER FULLY IMMERSED CONDITION OF CHLORIDE (HCL) MEDIA

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ABSTRACT

Al 2024 is an important engineering material, which is used in aerospace, marines, & automotive field. It is employed in many process industries cause of low density, High strength, corrosion resistance and low cost. The present study aims to investigate the corrosion behavior of Al 2024, under varying proportion of normality's and temperatures variation, respectively in chloride media. Corrosion testing is evaluated through fully immersion weight loss method in HCL solution with different Normality's that is 0.25N,0.50N,0.75, and 1N, at variation in temperature 300,600, 800 for 6, 12, 18, to 36 days. Corrosion characterization is done to investigate the effect of microstructure on its performance, and to study the effect of temperature on corrosion rate. The change in micro hardness is observed to be quite significant after being exposed to the chloride Acidic solution having pH 1 at different temperature for regular interval of 6 days over a period of 36 days. More-over, morphology and chemical compositions of corrosion behavior of Al 2024 under varying normality and temperature condition was analyzed through SEM and EDS.

KEYWORDS: Aluminum 2024, Localized Corrosion, HCL Solution, Weight Loss, Corrosion Rate, SEM & EDS

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Original Article

INTRODUCTION

Now days, the Aluminum alloy has been given important role as construction materials in the military and private sector. Aluminum alloy has low density, High strength, corrosion resistance and low cost. Low density material has huge demand on aerospace industries to development of exotic alloys. Due to limitations on satisfying the consumer's needs, their potential utilization has not yet been fully realized. The cause has been standard method of testing such materials for corrosion and corrosion resistance, everyone not satisfying with manufacture, fabrication and design [1].This method was not industry oriented, but rather environment oriented, such as materials qualification tests were performing on the standards there were available. Now, Technology has been advanced to change this sort of approach [2]. The aluminum alloys that are used in several Industries and their tests used must meet specific requirements [3]. The uses of the metal are extremely diverse due to unusual properties. Aluminum alloy such as used for heat-treated parts, airfoil and fuselage skins, extrusions, and fittings or aircraft fuselages, door skin, dorsal fin and trailing edge panel, automobile body as well as truck wheel rims and other structural application, due to their high strength and weight ratio, higher ductility and corrosive resistance [4]. Alloy can be affected from corrosion like as Pitting corrosion, Inter-granular Corrosion, stress corrosion cracking, Exfoliation corrosion, and galvanic corrosion [3]. Although corrosion mechanism of Al 2024have been previously investigated in chloride media, but for NACL, basic solution as per several studies was investigated [5-6]. Pitting corrosion is observed as Al alloys exposed to in aqueous environment. Traditionally, the cause of pitting

corrosion has been attacked on the passive film that takes shape on a metal surface. [7-8 to 9]

LITERATURE REVIEW

Hydrochloric acid is widely utilized in pickling of steel and aluminum structures, and acid cleaning, de-scaling processes, which lead to substantial loss of the metal due to corrosion reaction. Hydrochloric acid, in presence of seawater leads to formation of growing chloride ions. So, these donating free chloride ions (Cl^-) in an aqueous solution attack on metals, as a result of corrosion material get failure [10]. Chloride ions are usually extremely electro-negative and they are very reactive with sealed compounds and elements. This responsiveness is part of its usefulness, which is countermined by defiling, whereas, stainless steel is implicated. Although chloride is known to be the elemental agent of pitting attack, it is not possible to found a single decisive chloride value for the metals and alloys [11]. Pitting is only a breakdown of the passive layer, observed by localized corrosion that create pits, in steel vessels or pipes.

James et al [12] had studied the inhibition of the corrosion of aluminum in HCL solution by pyridoxol hydrochloride, by using weight loss method and gesso-metric techniques are used. The inhibition efficiency was increased with increasing inhibitor absorption and decrease with increase in temperature. Some of other investigation of the anodic of the grains part can be assigning to a high absorption of solute atoms in this region, as equated to grain interior found in [13-14].

V. Guillaumin et al [5] had studied the corrosion behavior of Al 2024 T351 alloy in 1 morality (NACL) solution. This work was to interpret the alloy towards inter-granular corrosion and localized corrosion from potential-kinetic Polarization curve. Whereas, G.S Chen et al [15] had studied the use of constituent particle in the pitting corrosion of Al 2024-T3, that was to investigated and correlate between characteristics of the particle and localized corrosion behavior. This experiment was conducted on air frame material Al 2024-T3 in 0.5M sodium chloride solution (NACL).

The present study aims to investigate the corrosion behavior of Al 2024 under different normality's at variation in temperature. ASTM standard by fully immersion weight loss method in HCL solution is with different Normality's that is 0.25N, 0.50N, 0.75, and 1N, at variation in temperature 30^0, 60^0, 80^0 for 6, 12, 18, to 36 days. Corrosion characterization is done to investigate the effect of microstructure on its performance. The change in micro hardness is observed to be quite significant after exposure to the deposits at different temperature for regular interval of 6 days over 36 days.

EXPERIMENTAL PROCEDUR

Material and Method

Al 2024 is an alloy with coppers, the main element. Due to poor corrosion resistance, we can weld this only through friction welding. This material can be used in aerospace and aircraft, door skin, structures, fuselage, trailing edge panels, dorsal fins, truck wheels rims, and crew machine products. Chemical composition or mechanical compositions are shown in table 1.

Table 1: Chemical Composition wt (%)

Alloy	Al 2024								
Component	AL	Mg	Si	Ti	Cr	Mn	Fe	Cu	Zn
Nominal	93.50	1.8	0.50	0.15	0.10	0.9	0.50	4.9	0.25

Table 2: Mechanical Properties

Properties	Metric	Imperial
Elastic modulus	80 G p a	10152 to11603 K s i
Passion ratio	0.33	0.33

Sample Preparation

Corrosion sample was prepared from a block of AL2024 alloy of dimensions 100mm×70mm×20 mm thick rectangular bar. Specimens were prepared by cutting machine in to this dimensions 37mm×33mm×20mm.The surface was polished with the diamond paste 3um or emery paper 320-400-600-2000 grade to get a starch free smooth surface and double polishing machine was used for surface finishing. Specimen was shown in figure 1.

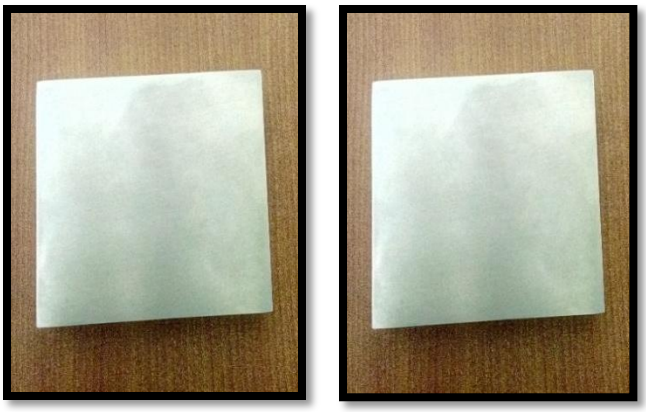


Figure 1: Showing the Specimen

Sample Cleaning Procedure

Specimens before experiment were cleaned with acetone or ethyl alcohol, distilled water and using the pickling solution. After cleaning, the specimens were kept in desiccators to remove the moisture form specimen. Then, the weight of each specimen was measured by advance four digits weighing machine. The weight of each specimen was found in grams.

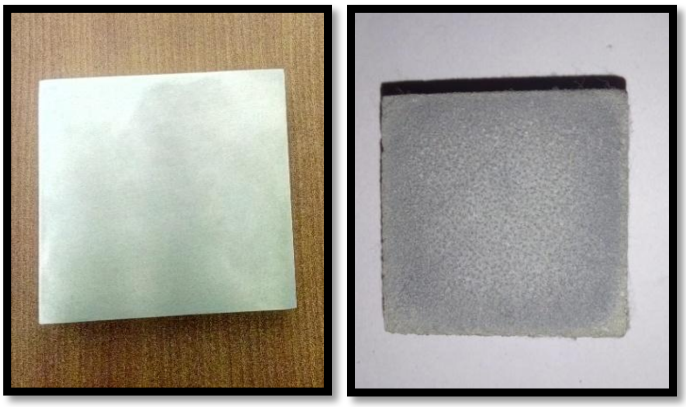
Corrosion Test Procedure

Al 2024 was used in exposure studies the size of specimens was 36mm×34mm×19mm thickness. Then material was soaked in glass beaker having volume of 250ml, in which100ml corrosive acidic HCL solution having pH 1was prepared in different normality 0.25, 0.50, 0.75, 1N. After that, these corrosive solution were utilized to carry corrosion study on various temperatures 30, 60, 80 to study the rate of corrosion utilizing weight loss method. The specimen samples were regularly weighed after initiation over interval of 6 day for a period of 36 days exposure to HCL solution with pH 1, as shown in figure 2. And figure 3.The samples were weighed periodically, after a regular interval of 6 days for continuous 36 days exposure to HCL solution with PH 1.

Figure 2: Test Specimen in HCL Solution

Figure 3: Test Specimen in Different Temperature

The specimen was fully immersed 3.5cm below the surface in the solution. The loss in weight of specimen sample was measured after being exposed to corrosive HCL solution. After dissolved the specimen were cleaned with acetone or ethyl alcohol, distilled water and the pickling solution. After cleaning, the specimen was kept in desiccators to remove the moisture from specimen. Then, the weight of each specimen was measured by advance four digits weighing machine for interval of 6 day, for a period of 36 days exposure to HCL solution with pH 1; in figure 4 and figure 5.



Before Corrosion Specimen **After Corrosion Specimen**

Figure 4: Corrosion Test Specimen

Figure 5: Specimens Weight Measure

After the corrosion test corroded surface of the sample were studied under scanning electron microscope.

Test Procedure

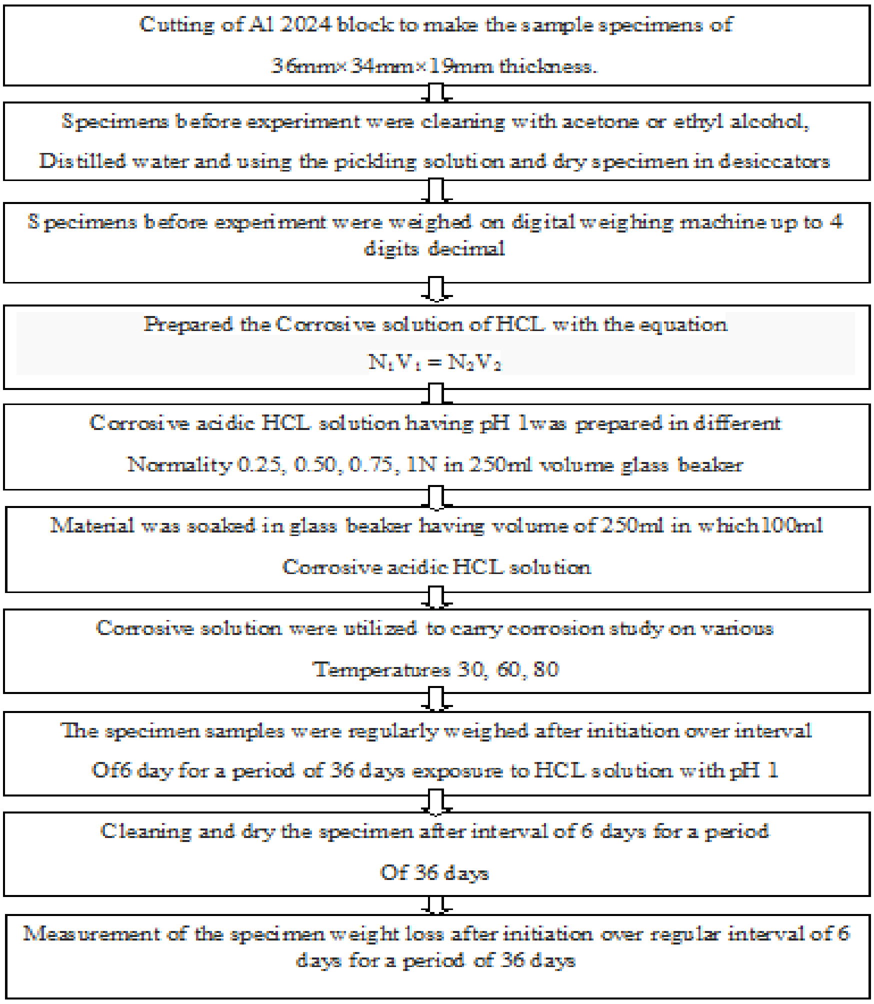


Figure 6

Measurement of Surface Roughness and Micro-Hardness

A roughness tester is used to determine the surface texture or surface roughness of a material accurately. A roughness tester shows the measured roughness depth (Rz) as well as the mean roughness value (Ra) in micrometers or microns (µm) Shown in figure 6.The surface roughness of Al 2024 material is 0.62 to 0.66 microns.

Figure 7: Surface Roughness Machine

Figure 8: Micro-Hardness Measurement Machine

The hardness of AL 2024 alloy was measured by micro Vickers hardness testing machine using 19mm thickness of aluminum. The hardness test was employed on five different specimens. A load of 1KG was used to determine the hardness of the material, because the material is very soft Shown in figure 7.

RESULTS AND DISCUSSIONS

The results of weight loss and corrosion rate for Al 2024 corrosion in 0.25N, 0.50N, 0.75N, 1N HCL solution with variation in temperature are shown in Figure 8(a), (b), (c), (d). It can be seen that the increase in temperature and acid absorption results in increase the corrosion rate shown in the graph. Therefore, absorption of CL ions destroys the passive film, which is tends to insulate the metal from the corrosive film. Corrosion rate of the material due to constitution of pits crack on the surface as absorbed on the sample. It was observed that corrosion rate decreases due to the intermetallic region. Severe Pitting corrosion was observed in the material surface, which is associated with the particle- matrix interface.

Effect of Corrosion on Weight Loss Due To Different With Normality and Temperature Variation

The corrosion behavior of Al 2024 in 0.25 N normality's at variation of temperature 30^0, 60^0, 80^0 for interval of 6, 12, 18, 24, 30 and 36 days was observed. Effect of temperature variation in 0.25N normality's on weight loss of Al 2024 in HCL solution shown in Figure 8(a), showing the weight loss with days on temperature variation of 0.25N normality, and sample was fully immersed in solution HCL of different normality. The total weight loss % of specimen (1) 0.25N on 30^0temperatures in 36 days is 2.75% and specimen (5) total weight loss % in 0.25N on 60^0 temperatures in 36 days is 3.82% and specimen (9) total weight loss % in 0.25N on 80^0 temperatures in 36 days is 10.29%. It can be seen that the total weight loss % is increased with the increase in temperature shown in graph. The corrosion behavior of Al 2024 in 0.50 N normality's at variation of temperature 30^0, 60^0, 80^0 for interval of 6, 12, 18, 24, 30 and 36 days. Effect of temperature variation in 0.50N normality's on weight loss of Al 2024 in HCL solution shown in Figure 8(b). The total weight loss % of specimen (2) in 0.50N on 30^0temperatures in 36 days is 4.28% and specimen (6) total weight loss % in 0.50N on 60^0 temperatures in 36 days is 14.40 % and specimen (10) total weight loss % in 0.50N on 80^0 temperatures in 36 days is 18.03%. It can be seen that the total weight loss % increases with the increase in temperature shown in graph. The corrosion behavior of Al 2024 in 0.75 N normality's at variation of temperature 30^0, 60^0, 80^0 for interval of 6, 12, 18, 24, 30 and 36 days. Effect of temperature variation in 0.75N normality's on weight loss of Al 2024 in HCL solution shown in Figure 8(c). The total weight loss % of specimen (3) in 0.75N on 30^0temperatures in 36 days is 5.54% and specimen (7) total weight loss % in 0.75N on 60^0 temperatures in 36 days is 17.21 % and specimen (11) total weight loss % in 0.75N on 80^0 temperatures in 36 days is 27.64%. It can be seen that the total weight loss % is increase with the increase in temperature shown in graph. The corrosion behavior of Al 2024 in 1 N normality's at variation of temperature 30^0, 60^0,for interval of 6, 12, 18, 24, 30 and 36 days. Effect of temperature variation in 1N normality's on weight loss of Al 2024 in HCL solution shown in Figure 8(d). The total weight loss % of specimen (4) in 1N on 30^0temperatures in 36 days is 8.99% and specimen (8) total weight loss % in 1N on 60^0 temperatures in 36 days is 22.65 %.

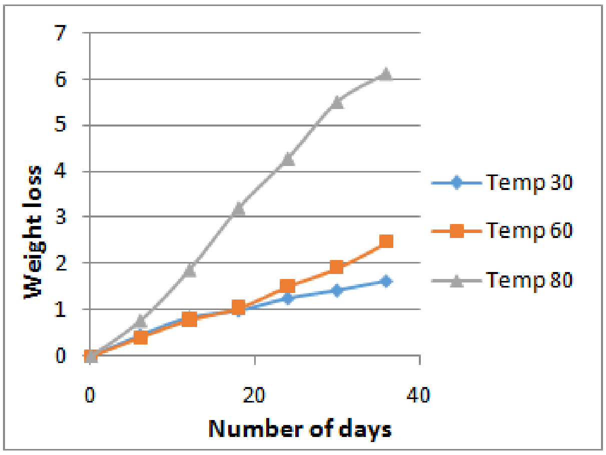


Figure 9(a): 0.25N

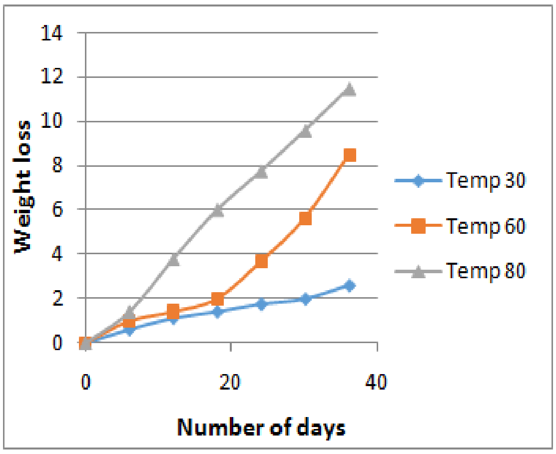


Figure 9(b): 0.50N

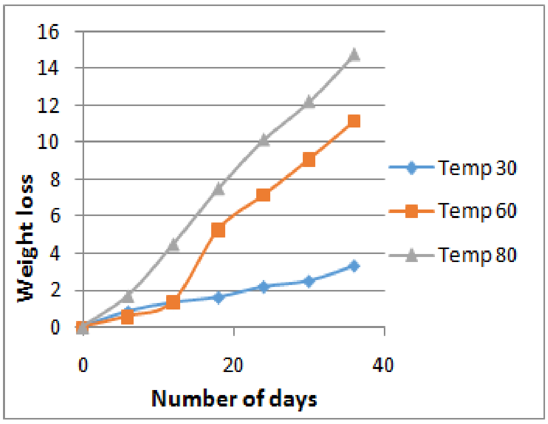


Figure 9(c): 0.75N

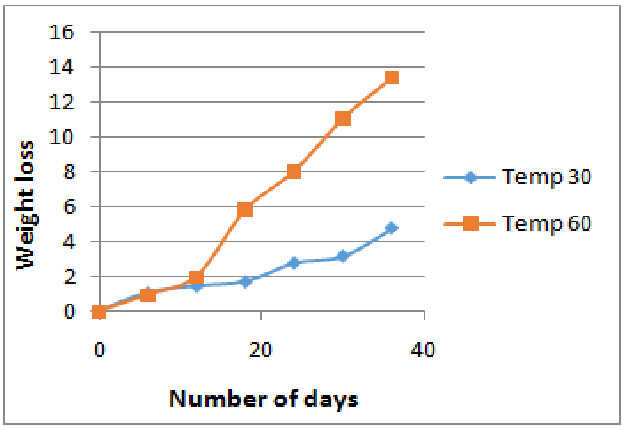


Figure 9(d): 1N

The interval of time 6, 12, 18, to 36 days the weight loss increased gradually caused due to increase in temperature, therefore, rose in acid concentration. The corrosion behavior of the Al 2024 due to the constitution of pits cracks on the surfaces as absorbed on the sample. It can be seen that higher concentration of HCL ions destroy the passive film of the surface, which as tends to insulate the metal from of corrosive solution. A similar pattern was absorbed in weight loss of Al 2024 on different normality, whereas, with increased temperature, the weight loss was seen due to corrosion seen in graph.

Effect of Normality Variation on Weight Loss of Al 2024 Held in Specific Temperature

The corrosion behavior of Al 2024 in different normality's at variation on temperature $30^0$for interval of 6, 12, 18, 24, 30 and 36 days was observed. Effect of normality's variation 0.25N, 0.50N, 0.75N, 1N normality's on weight loss of Al 2024 in HCL solution shown in figure 9(a) shows the weight loss with days on normality variation of 0.25N, 0.50N, 0.75N, 1N normality and sample was fully immersed in HCL solution on 30^0 temperatures. First 6 days, the weight loss increased gradually and after 12 days weight loss increased. The corrosion behavior of the Al 2024 due to the constitution of pits cracks on the surfaces. A similar pattern was absorbed in weight loss of Al 2024 in different normality, whereas with increase in solution the weight loss was seen due to corrosion on 30^0 temperatures seen in graph.

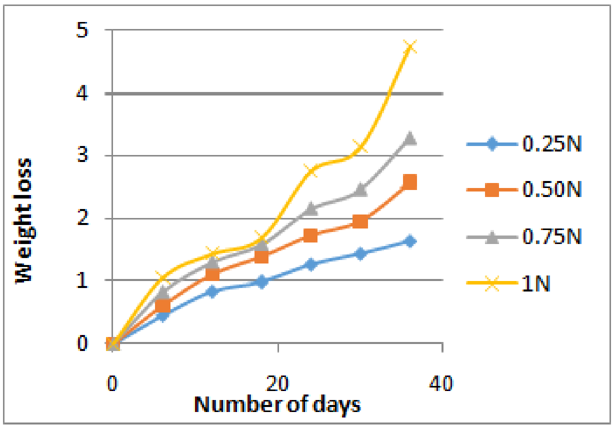


Figure 10(a): 30^0 Temperature

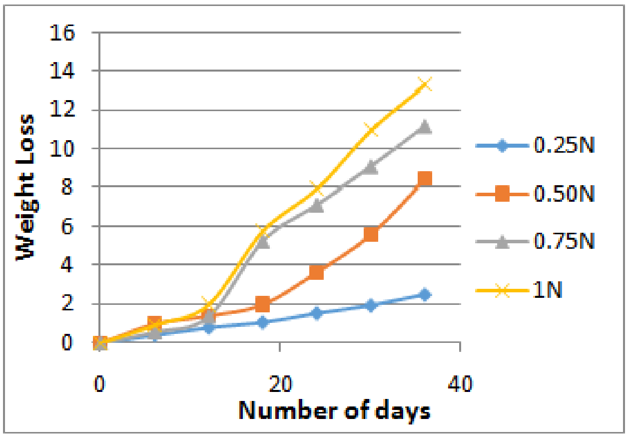


Figure 10(b): 60^0 Temperature

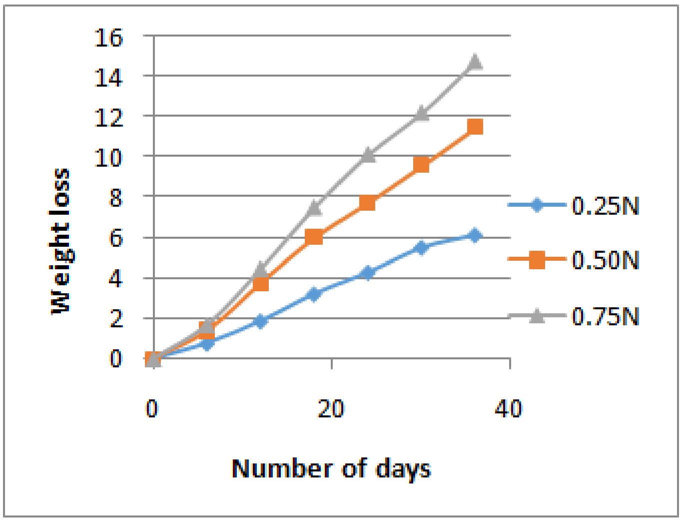


Figure 10(c): 80^0Temperature

Effect of normality's variation 0.25N, 0.50N, 0.75N, 1N normality's on weight loss of Al 2024 in HCL solution shown in figure 9(b) shows the weight loss with days on normality variation of 0.25N, 0.50N, 0.75N, 1N normality and sample was fully immersed in HCL solution on 60^0 temperatures. The first 6 days, the weight loss increased gradually and after 12 days weight loss increased in 0.25N normality's on temperature 60^0 and normality's variation 0.50Non 60^0 temperatures in 6 days the weight loss increased and another after 12 days weight loss increased due to corrosion and therefore, 0.75 normality or 1N on 60^0 temperatures in 6 days, weight loss increased and after 12 days weight loss increased and 1N in 6 days the weight loss increased and after 12 days the weight suddenly increased, a similar pattern absorbed due to corrosion, it can be seen that in graph. The effect of normality's variation 0.25N, 0.50N, 0.75N, normality's on weight loss of Al 2024 in HCL solution shown infigure9(c) showing the weight loss with days on normality variation of 0.25N, 0.50N, 0.75N, normality and sample was fully immersed in HCL solution on 80^0 temperatures. The first 6 days, the weight loss increased gradually and after 12 days weight loss increased in 0.25N normality's on temperature 80^0 and normality's variation 0.50N on 80^0 temperatures, in 6 days the weight loss increased and another after 12 days weight loss increased due to corrosion and therefore, 0.75 normality on 80^0 temperatures in 6 days, weight loss increased and after 12 days weight loss increased, a similar pattern absorbed due to corrosion, it can be seen that in graph. The corrosion behavior of al 2024 due to the constitution of pits cracks on the cracks.

Corrosion Rate

Temperature has a great effect on the corrosion phenomenon. Mostly, the corrosion rates increase with increase of temperature. The total corrosion rate can be calculated for 36 days. The Corrosion rate unit taken was in (mm/py) i.e. (65.789 mm/py)

Corrosion Rate can be calculated using

$$C.R = \frac{K \times W}{A \times T \times D} \qquad \text{(Equation1)}$$

Where C.R = is the Corrosion rate, K = Constant, W = Total weight loss, A = Surface area of the specimen, T = Time, D = Density of the metal in gm/cm^2

Effect of Corrosion on Corrosion Rate Due to Different With Normality and Temperature Variation

The corrosion behavior of Al 2024 in variation of normality's on temperature 30^{0}for interval of 6, 12, 18, 24, 30 and 36 days was observed. Effect of normality's variation 0.25N, 0.50N, 0.75N, 1N normality's on corrosion rate of Al 2024 in HCL solution shown in figure 10(a) shows the corrosion with days on normality variation of 0.25N, 0.50N, 0.75N, 1N normality, and sample was fully immersed in HCL solution on 30^0 temperatures. First 6 days, the weight loss increased gradually and after 12 days weight loss increased. The corrosion behavior of the Al 2024 was due to the constitution of pits cracks on the surfaces. A similar pattern absorbed in weight loss of Al 2024 in different normality, whereas with increased the solution the corrosion rate was seen due to acid concentration on 30^0 temperatures seen in graph. In figure 10(b) and figure 10 (c) first 6 days the weight loss increased gradually and after 12 days weight losses increased.

The corrosion behavior of the Al 2024 was due to the constitution of pits cracks on the surfaces. It can be seen that higher concentration of HCL ions destroys the passive film of the surface, which inclines to insulate the metal from of corrosive solution. A similar pattern absorbed in corrosion rate of Al 2024 on different normality, whereas with increased temperature, the corrosion rate was seen due to corrosion seen in graph.

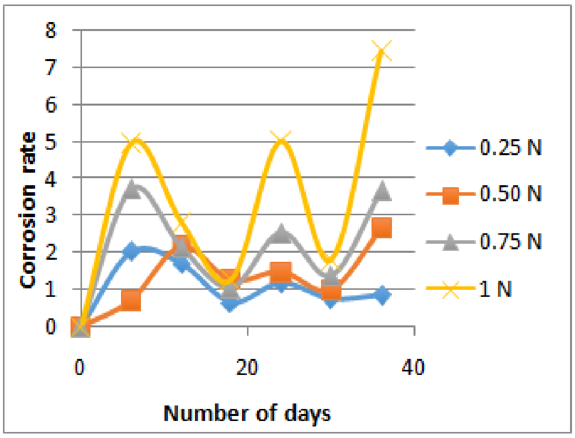


Figure 11(a): 30^0 Temperature

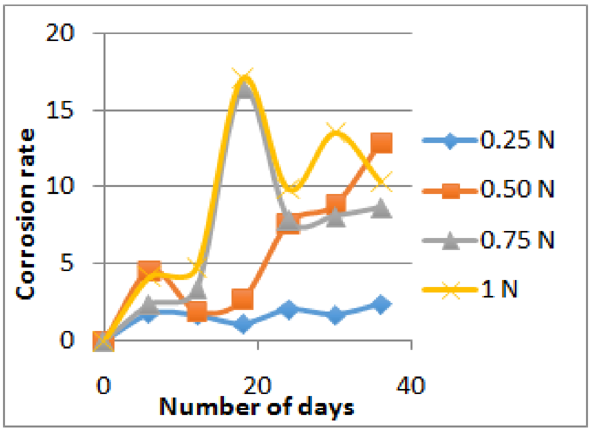


Figure 11(b): 60^0 Temperature

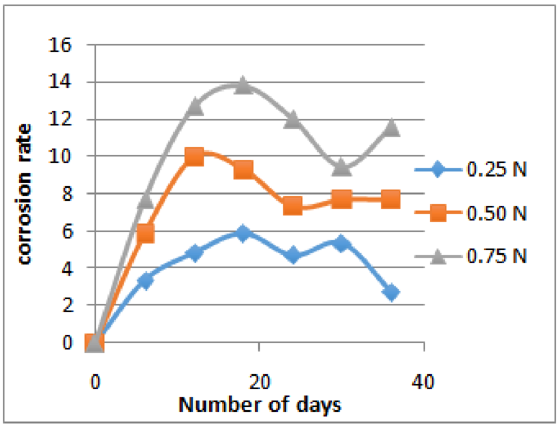


Figure11 (c): 80^0Temperature

Effect of Normality Variation on Corrosion of Al 2024 Held in Specific Temperature

Effect of temperature variation in 0.25N normality's on corrosion rate of Al 2024 in HCL solution shown in Figure 11(a) shows the corrosion rate with days on temperature variation of 0.25N normality and sample was fully immersed in solution HCL of different normality. The total corrosion rate % of specimen (1) in 0.25N on 30^0temperatures in 36 days is 12.27% and specimen (5) total corrosion rate % in 0.25N on 60^0 temperatures in 36 days is 16.75% and specimen (9) total corrosion rate % in 0.25N on 80^0 temperatures in 36 days is 45.13%. It can be seen that the total corrosion rate % is increase with the increase in temperature shows in graph. The corrosion behavior of Al 2024 in 0.50 N normality's at variation of temperature 30^0, 60^0, 80^0 for interval of 6, 12, 18, 24, 30 and 36 days. Effect of temperature variation in 0.50N normality's on corrosion rate of Al 2024 in HCL solution shown in figure 11(b). The total corrosion rate % of specimen (2) in 0.50N on 30^0temperatures in 36 days is 15.53% and specimen (6) total corrosion rate % in 0.50N on 60^0 temperatures in 36 days is 65.70 % and specimen (10) total corrosion rate % in 0.50N on 80^0 temperatures in 36 days is 75.98%. It can be seen that the total corrosion rate % is increase with the increase in temperature shown in graph. The corrosion behavior of Al 2024 in 0.75 N normality's at variation of temperature 30^0, 60^0, 80^0 for interval of 6, 12, 18, 24, 30 and 36 days. Effect of temperature variation in 0.75N normality's on corrosion rate of Al 2024 in HCL solution shown in Figure 11(c). The total corrosion rate % of specimen (3) in 0.75N on 30^0temperatures in 36 days is 24.93% and specimen (7) total corrosion rate % in 0.75N on 60^0 temperatures in 36 days is 72.34% and specimen (11) total corrosion rate % in 0.75N on 80^0 temperatures in 36 days is 85.43%. It can be seen that the total corrosion rate % is increase with the increase in temperature variation shown in graph. The corrosion behavior of Al 2024 in 1 N normality's at variation of temperature 30^0, 60^0,for interval of 6, 12, 18, 24, 30 and 36 days. Effect of temperature variation in 1N normality's on corrosion rate of Al 2024 in HCL solution shown in figure 11(d). The total corrosion rate % of specimen (4) in 1N on 30^0temperatures in 36 days is 42.16% and specimen (8) total corrosion rate % in 0.75N on 60^0 temperatures in 36 days is 90.23 %.

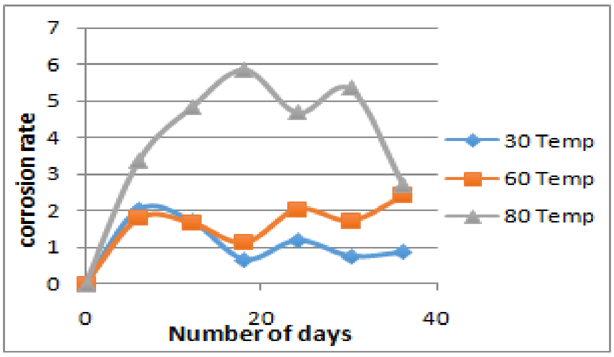


Figure 12(a): 0.25N

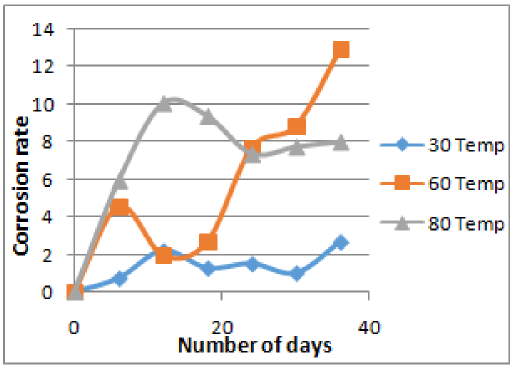


Figure 12(b): 0.50N

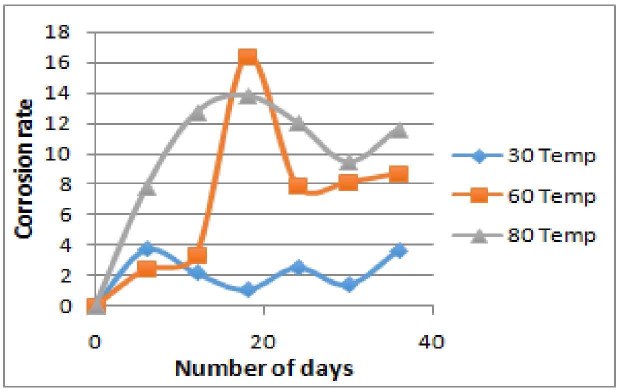


Figure 12(c): 0.75N

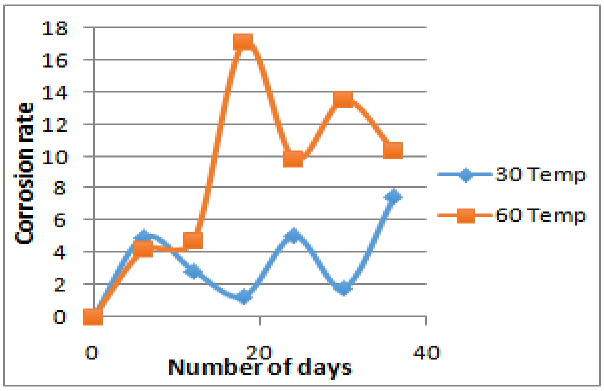


Figure 12(d): 1N

In the interval of time 6, 12, 18, to 36 days, the corrosion rate increased gradually due to increase in temperature, therefore raised in acid concentration. The corrosion behavior of the Al 2024 was due to the constitution of pits cracks on the surfaces, as absorbed on the sample. It can be seen that higher concentration of HCL ions destroys the passive film of the surface, which incline to insulate the metal from of corrosive solution. A similar pattern absorbed in corrosion rate of Al 2024 on different normality, whereas with increased temperature, the corrosion rate was seen as shown in the graph.

Combined Results for Temperature and Normality Variation

The weight loss results and corrosion rates for Al 2024 corrosion in 0.25N, 0.50N, 0.75N, and 1N HCL acid solution with temperature at 30^0,60^0 and 80^0 are shown in Table 2. It was found that increase in either temperature or concentration of the acid solution led to rise in corrosion rate. As shown in figure 12, as temperature was increased, corrosion rate also increased because of rise in acid concentration with pH 1.

Table 3: Values of Al 2024 Weight Loss and Corrosion Rate at different Concentrations of (HCL) at different Temperatures

Temp(C)	30^0C		60^0C		80^0C	
Conc. (N)	Wt. Loss (g)	Corrosion Rate (mm/py)	Wt. Loss (g)	Corrosion Rate(mm/py)	Wt. Loss (g)	Corrosion Rate (mm/py)
0.25N	1.6217	7.2274	2.4611	10.775	6.1169	26.8239
0.50N	2.5771	9.3502	8.4409	38.5152	11.4430	48.2095
0.75N	3.2359	14.5576	11.1359	46.8075	14.7302	67.2927
1N	4.9812	23.3505	13.3455	59.8761		

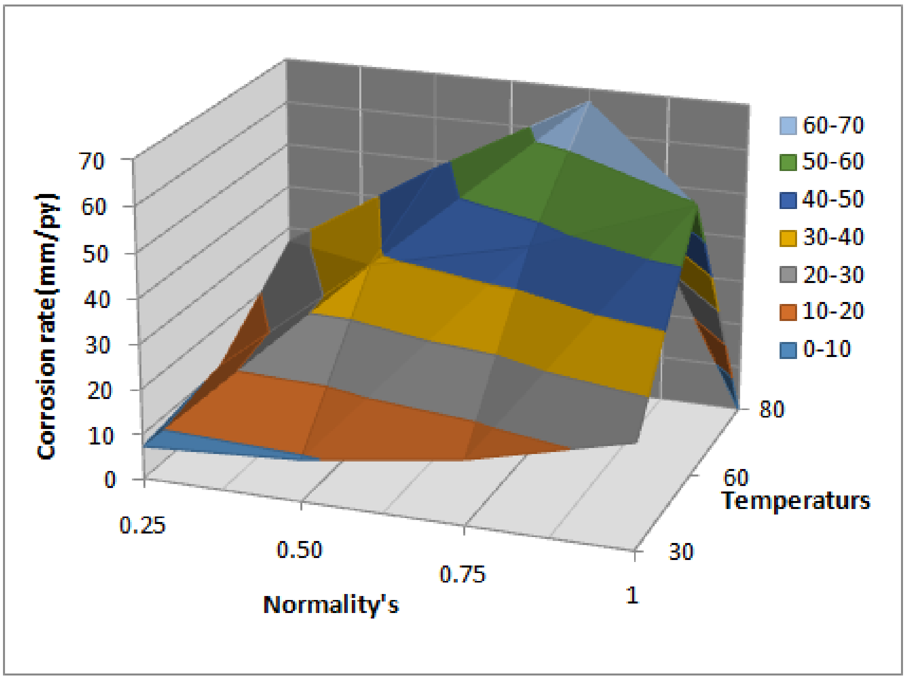


Figure 13: Showing the Variation of Corrosion Rate as a Function Temperature and Acid Concentration

Measurement of Surface Roughness and Micro-Hardness

The surface roughness of the Al 2024 material is 0.62 to 0.66 microns. Micro-Vickers Hardness of the Al 2024 in different normality's 0.25N, 0.50N, 0.75N, 1N on 30^0 Temperature. Micro-Vickers hardness of base metal is 88HV and other corrosion sample Micro-Vickers hardness in different normality's is 0.25N (76HV), 0.25N (81HV), 0.75N (83HV) and 1N (85HV) shown in the figure 13. In 0.25N, 0.50N, 0.75N and 1N corrosion specimen hardness is decrease due to the corrosion in 36 days.

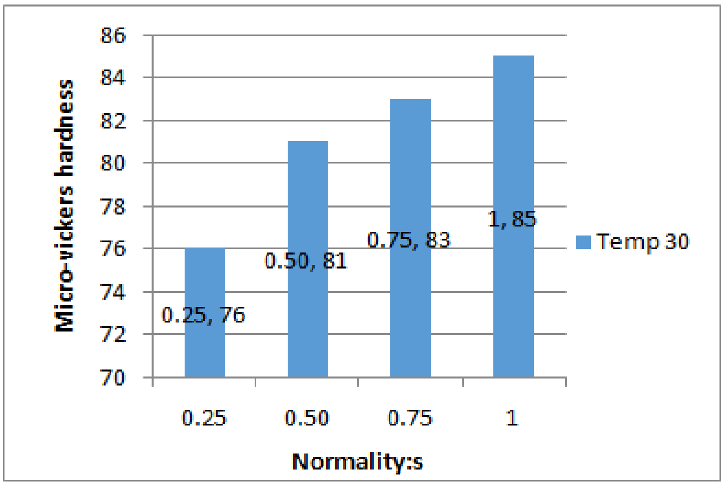
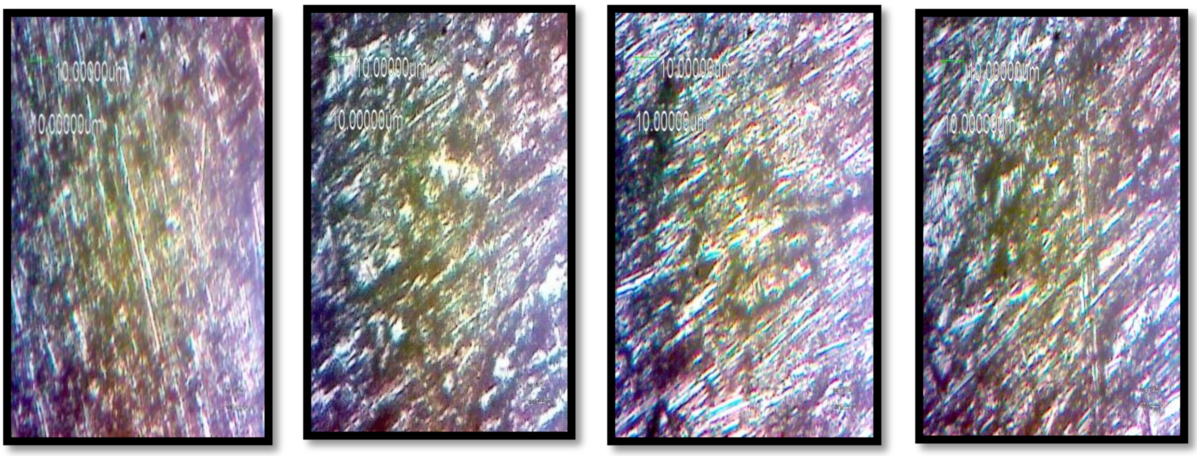


Figure 14: Showing the Micro-Vickers Hardness of Corrosion Specimen at Different Normality's

Microstructure

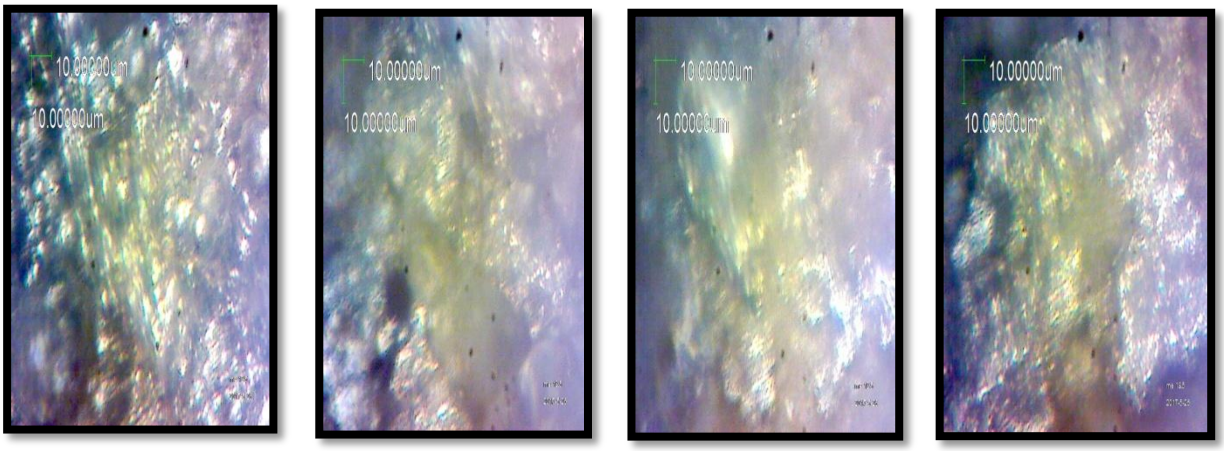
An optical microscope was used to analyze the specimen surface for morphological changes after the full immersion test of Al 2024. Optical microscope was used to capture images of alloy before and after corrosion. Optical

micrograph for the same area of Al 2024 specimens shown in figure 14(a), (b), (c), (d) the polished surface as the rolling direction of the bar, from top to the bottom of the micrograph and figure (e), (f), (g), (h) are showing the same surface after 36 days corrosion in different normality 0.25N (1) specimen, 0.50N (2) specimen, 0.75N (3) specimen, 1N (4) specimen on 30^0 temperatures. Susceptibility to inter-granular corrosion and localized corrosion depends upon the microstructure of alloy. Grain boundaries were attacked on surface and large pits developed within the grains. The pits were showed in crystallographic aspect i.e. tendency to rise following sealed crystal planes can be as curtained in Figure 15a.



Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Figure 14(a)	**(b)**	**(c)**	**(d)**

Figure 15: (a), (b), (c), (d) Specimen Sample before Corrosion



Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
(e)	**(f)**	**(g)**	**(h)**
HCL 0.25N	**HCL 0.50N**	**HCL 0.75**	**N HCL 1N**

Figure 15: (e), (f), (g), (h) Specimen Sample after Corrosion

SEM & EDS

Electron microscopy has the proficiency that can be used as an electron beam to image a specimen. The smaller wavelength of electron beam makes it potential to achieve a resolution, importantly better than a light microscope. A beam of electrons is produced at the top of a scanning electron microscope from thermionic gun or field emission electron gun during SEM operation, charging and longtime electron hitting may affect the specimen surface condition and image

quality. The basic principle behind scanning electron microscopy (SEM) is that, a beam of electrons is focused and scanned across a sample surface and provides high-resolution and increased depth-of-field images of the sample surface. Scanning electron microscopy (SEM) & Energy dispersive x-ray spectrometry was used to enquire the chemical composition or morphology of the specimen surface and consistent partials, because, the corrosion behavior of the specimen was found by the SEM, especially with electron beam at operating voltage at high magnification.

Specimens were firstly analyzed by optical microscopy. Then, an observation by the scanning electron microscopy SEM was performed with an in order to study the behavior of the localization of pits or inter-granular attack. The energy dispersed spectrometry EDS analysis were performed during SEM an observation to study the development of the intermetallic particle composition. SEM images, identical of the alloy surface after 36 days of fully immersion in 0.25N, 0.50 N, 0.75N and 1N on 30^0 temperatures is shown in figure 15(a). The morphology and chemical composition of the particles for a specimen after 30 days corrosion test is given. The particle containing Al -cu-Fe, and Mn was found to promote the crystallization dissolution leaving slight ditch at the outer boundary. The particles that dissolved, therefore, appeared to have mostly cu particles left. P and Cr have shown by the peaks in the EDS spectra.

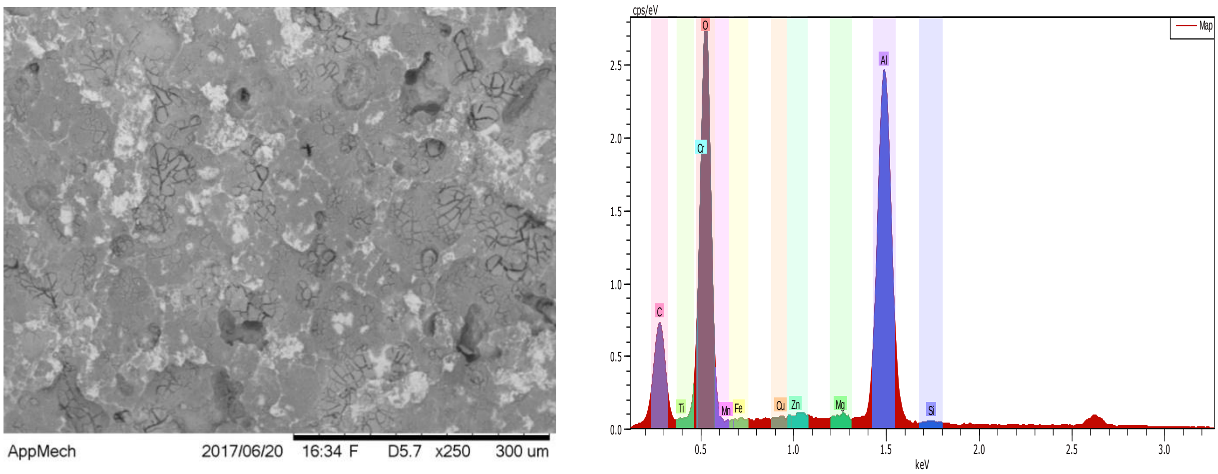


Figure 16(a): SEM Images of Identical Zone and EDS of the Al 2024 Surface after Corrosion 0.25N on 30^0 Temperatures

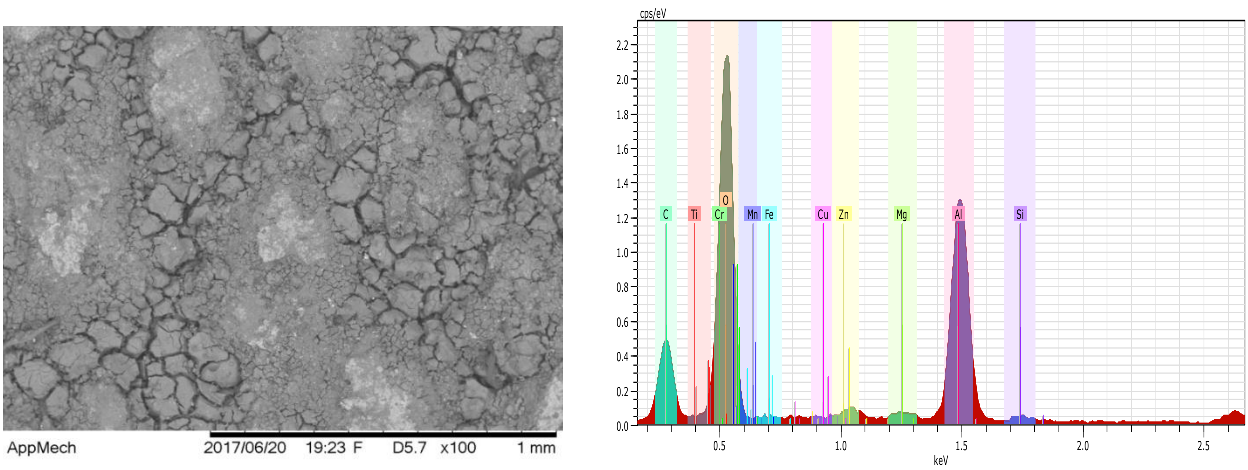


Figure 16(b): SEM Images of Identical Zone and EDS of the Al 2024 Surface after Corrosion 0.50N on 30^0 Temperatures

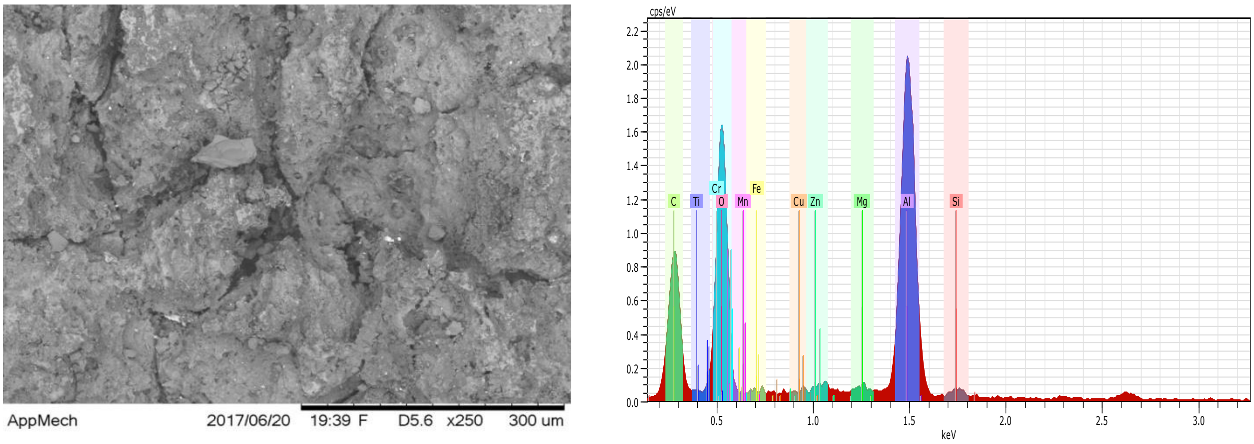


Figure 16(c): SEM Images of Identical Zone and EDS of the Al 2024 Surface after Corrosion 0.50N on 30^0 Temperatures

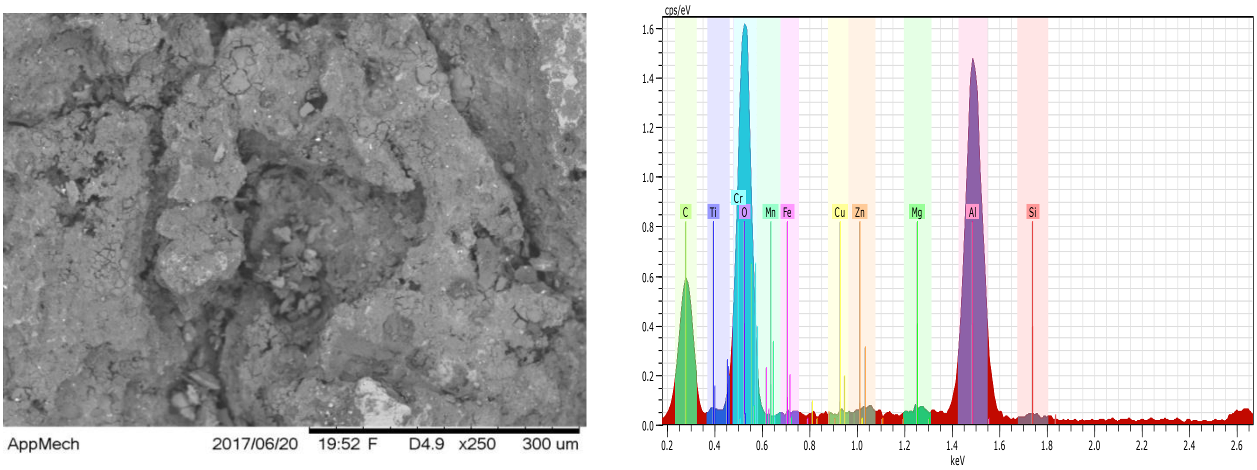


Figure 16(d): SEM Images of Identical Zone and EDS of the Al 2024 Surface after Corrosion 1N on 30^0 Temperatures

They represent the residuals from chemical cleaning. More important Cu deposition was discovered on the Al - Cu - Mn - Fe – containing particles with nodular Cu deposited on those particles, irrespective of their size. The phenomenon is similar to that of deposition corrosion [16]. Corrosion for long periods of time led to development of individual pits or cracks in breadth and depth, causing the formation of larger pits through by the coalescence. Accelerated corrosion damage by the particles- nucleated pitting in the Al 2024.

CONCLUSIONS

The corrosion of AL2024 in acidic chloride (HCL) with pH solution has been investigated by using weight loss technique over a period of 36 days, in full immersion solution of HCL. The following could be inferred as observed from the experimental data.

- Increase in temperature of HCL solution led to higher dissolution of chloride ions with rise in temperature and so decreased corrosion resistance efficiency of Al2024.
- The corrosion rate of the Al 2024 was found to be subject on both temperature variation and acid concentration.

- The weight loss revealed that maximum corrosion rate was found to happen at 1N HCL at temperature 80^0C.
- Results obtained showed that in corrosion reaction of AL2024, the corrosion rate was found to increase with increasing temperature and acid concentration.
- Susceptibility to inter-granular corrosion and localized corrosion depends upon the microstructure of alloy. Grain boundaries were attacked on surface and large pits developed within the grains.

REFRENCES

1. *"Aluminum Information at aircraftspruce.com" accessed August 15, 2011.*
2. *Alior W.H "Atmospheric factor affecting the corrosion of Enggering material" ASTM STP 646 S. k. coburn. Philadelphia, 1976, p.129.*
3. *3.Kucera,V. and gullman, J .in "Electrochemical method for corrosion testing" ASTM STP727 f. Mansfeld, ED, Amrican society for testing and material Philadelphia,1981, p.238.*
4. *G.s chen, M.gao " Micro-constituent-induced pitting corrosion in aluminum alloy 2024-T3"*
5. *Valerie guillaumin, Georegesmankowski in" localized corrosion of 2024 T351aluminum alloy in chloride media".*
6. *DR. Volkan cicek, "Environmentally friendly corrosion inhibition of sol-gel coated al 2024-T3 alloy via inhibitor pigment enrichment".*
7. *Metals Handbook, 9th ed., vol. 13, "Corrosion" (Materials Park, OH: ASM Int., 1987), p. 113.*
8. *Z. Szklarska- Smialowska, "Corrosion"27 (1971): p. 223.*
9. *J. Zahavi, M. Metzger, "Breakdown of Films and Initiation of Pits on Aluminum during Anodizing, in Localized Corrosion" Int. Corros. Conf. Series, NACE-3, eds. R.W. Staehle, B.F. Brown, J. Kruger, and A. Agrawal (Houston, TX: NACE, (1974), p.547.*
10. *Wang, R. and Kido, M. (2009) "Influence of Input Power to Vibrator and Vibrator-to-Specimen Distance of Ultrasound on Pitting Corrosion" of SUS304 Stainless Steel in 3.5% Chloride Sodium Aqueous Solution. Corrosion Science, **51**, 1604-1610.http://dx.doi.org/10.1016/j.corsci.2009.04.007.*
11. *Huang, Y.L., Cao, C.N., Lu, M. and Lin, H.C. (1993) "Inhibition Effects of I− and I2 on Stress Corrosion Cracking of Stainless Steel in Acidic Chloride Solutions" Corrosion, **49**, 644-649. http://dx.doi.org/10.5006/1.3316095*
12. *James A.O., Oforka N., Abiola O.K., Inhibition of Aluminium (3SR) "Corrosion in hydrochloric acid by pyridoxol hydrochloride" (Department of Pure and Industrial Chemistry, University of Port Harcourt, Port Harcourt, Nigeria P.M.B.5323), Bulletin of Electrochemistry 22(3) (2006)111-116(Eng).*
13. *D[E[Davies\ J[P[Dennison\ M[L[Mehta\ in] R[W[Staehle et al["Eds[#\ "International Conference on Localized Corrosion" National Association of Corrosion Engineers\ Houston\ TX\ 0860\ pp[597_502].*
14. *P. Doig\ P[E[J[Flewitt J[W[Edington\ "Corrosion"22 "0866# 106*
15. *Metals Handbook, 9th ed., vol. 13, "Corrosion" (Materials Park, OH: ASM Int., 1987), p. 113*
16. *Z. Szklarska- Smialowska, "Corrosion" Sci. 41 (1999) 1743.*